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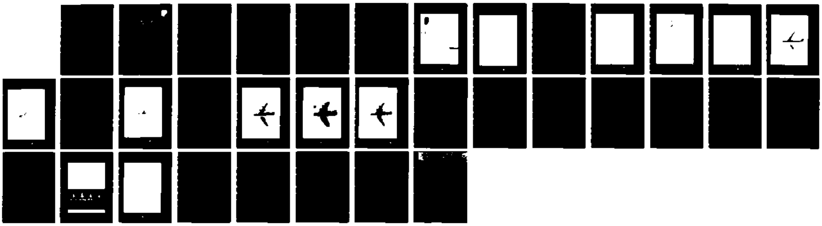

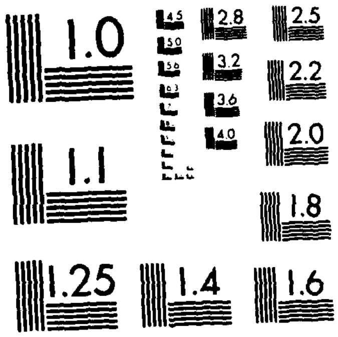

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RADC-TR-83-110
Interim Report
April 1983

SHAPE DISCRIMINATION ANALYSIS OF TACTICAL GROUND TARGETS

Purdue University

O. R. Mitchell and T. A. Grogan

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This interim report identifies the most significant problem in shape discrimination as the extraction of the shape from the background (segmentation). It further describes the investigation and applicability of fourier shape descriptors to the recognition of tactical targets in aerial imagery.

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The purpose of this research project is to investigate the applicability of Fourier and other shape descriptors to the recognition of tactical targets in aerial imagery. The work to-date has concentrated on a few test images supplied by Rome Air Development Center. We have found that the most significant problem in this particular type of data is the extraction of the shape from the background (segmentation).

Two segmentation methods have been investigated. The first involves local thresholding based on the grey values along detected edges in the image. This method was discussed in the Progress Report dated July 24, 1981. Another approach which has proven more useful for the type of data tested involves the location of potential objects based on grey level/edge level combinations which are unique to the local background where they are found.

Once the segmentation is accomplished, the contours around each object are extracted and normalized Fourier descriptors are calculated. These normalized Fourier descriptors are then compared to library entries of known targets and all recognized contours are identified.

II. Segmentation

Consider the original image shown in Fig. 1. The first step in automatically recognizing the airplanes in the image is to extract the contours from the background. In infrared imagery with hot targets, the object extraction may become simpler.

The method which we have found most useful involves two stages. First, potential target regions are found which differ from the more common background region. Second, each potential target region is closely inspected and any object unique in grey level and edge content is extracted from the background.

A. Potential Target Location

The assumption made in this section is that combinations of grey value and edge value that occur infrequently over the entire image may be on potential targets and should be investigated further. The edge feature picture is derived so that the brightness of each point is proportional to the edge content in a window surrounding that point. The Sobel edge operator[1] is used to produce the edge picture shown in Fig. 2.

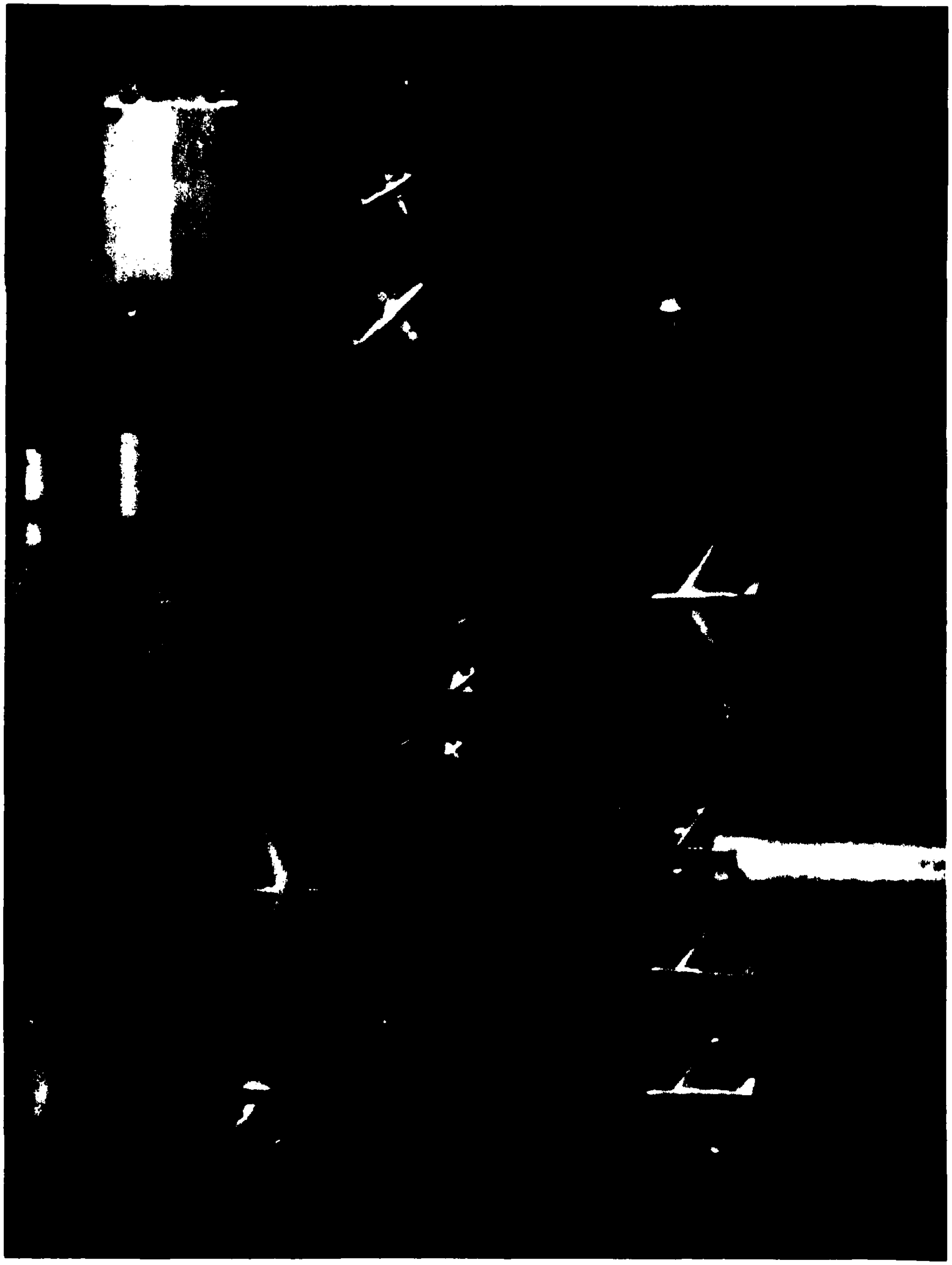

Fig. 1. Original image containing airplanes to be segmented and recognized. 512x512 pixels with 256 grey levels.

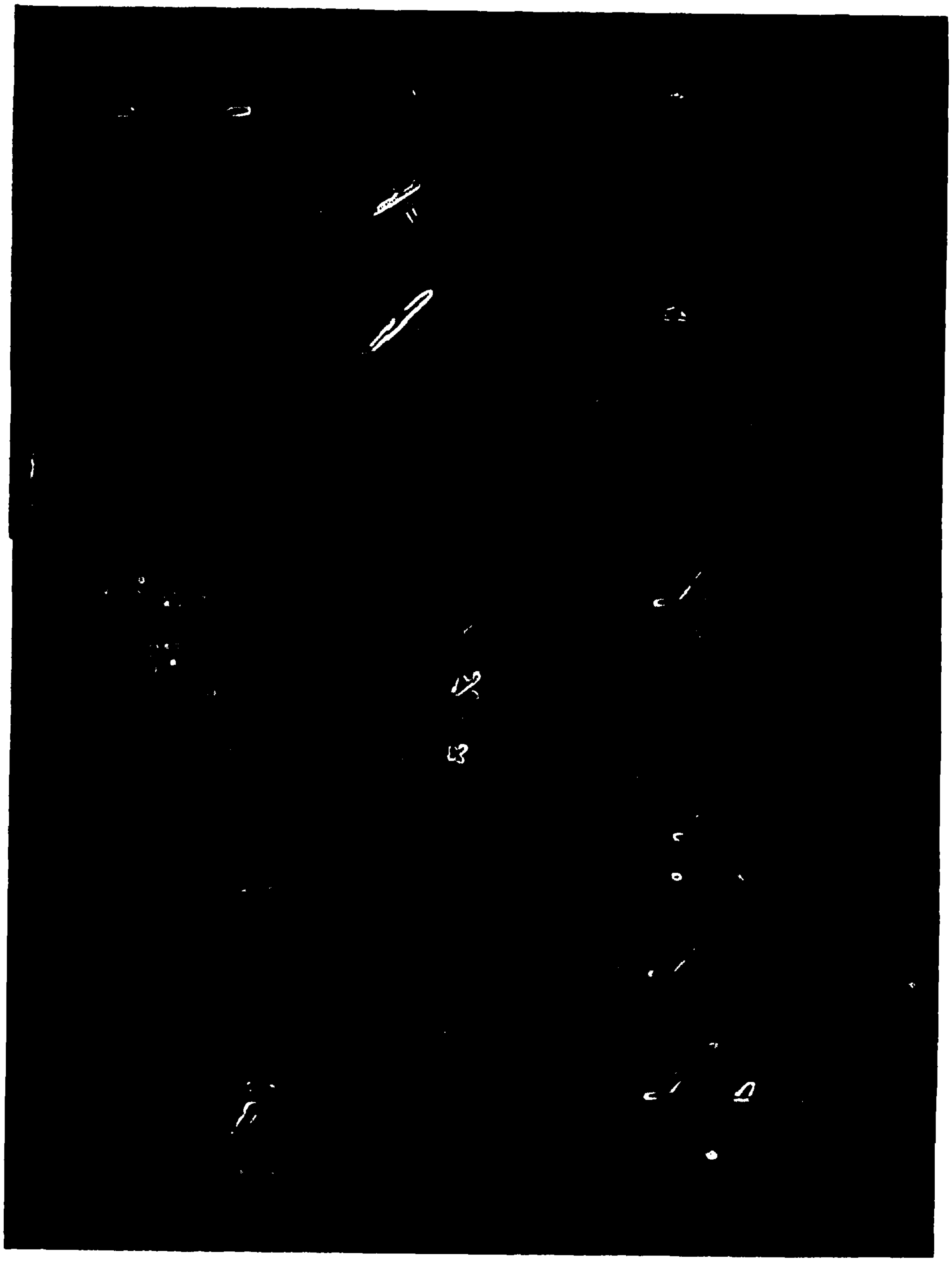

Fig. 2. Edge picture produced by the Sobel edge operator.

For purposes of finding unique regions, the grey level image is quantized to 32 levels and the edge image is quantized to 8 levels. Each pixel may now be considered a two-dimensional vector (grey value and edge value) and a two-dimensional histogram is created from the input images. Points in the original image are next located whose two-value combination occurs infrequently. Shown in Fig. 3 are all such locations having a combination occuring less than 100 times in the entire image. The location of potential targets is then made by finding concentrated clusters of such points.

This is done by averaging Fig. 3 over a circular window of diameter 14 and then detecting local maxima in the averaged result. The result of averaging is shown in Fig. 4 and the local maxima are shown in Fig. 5. These points represent the potential target locations in the original image (Fig. 1). Note that all 12 aircraft as well as additional objects are marked as potential targets.

B. Potential Target Extraction

The next step in the process is to select the grey level and edge images in a small (100x100) region surrounding each potential target point. The large airplane at the bottom center of Fig. 1 is shown in Fig. 6 (a) and (b).

Segmentation of the object from the background is obtained by assuming at least part of the object is in the center of the image and generating a two-dimensional histogram of the object

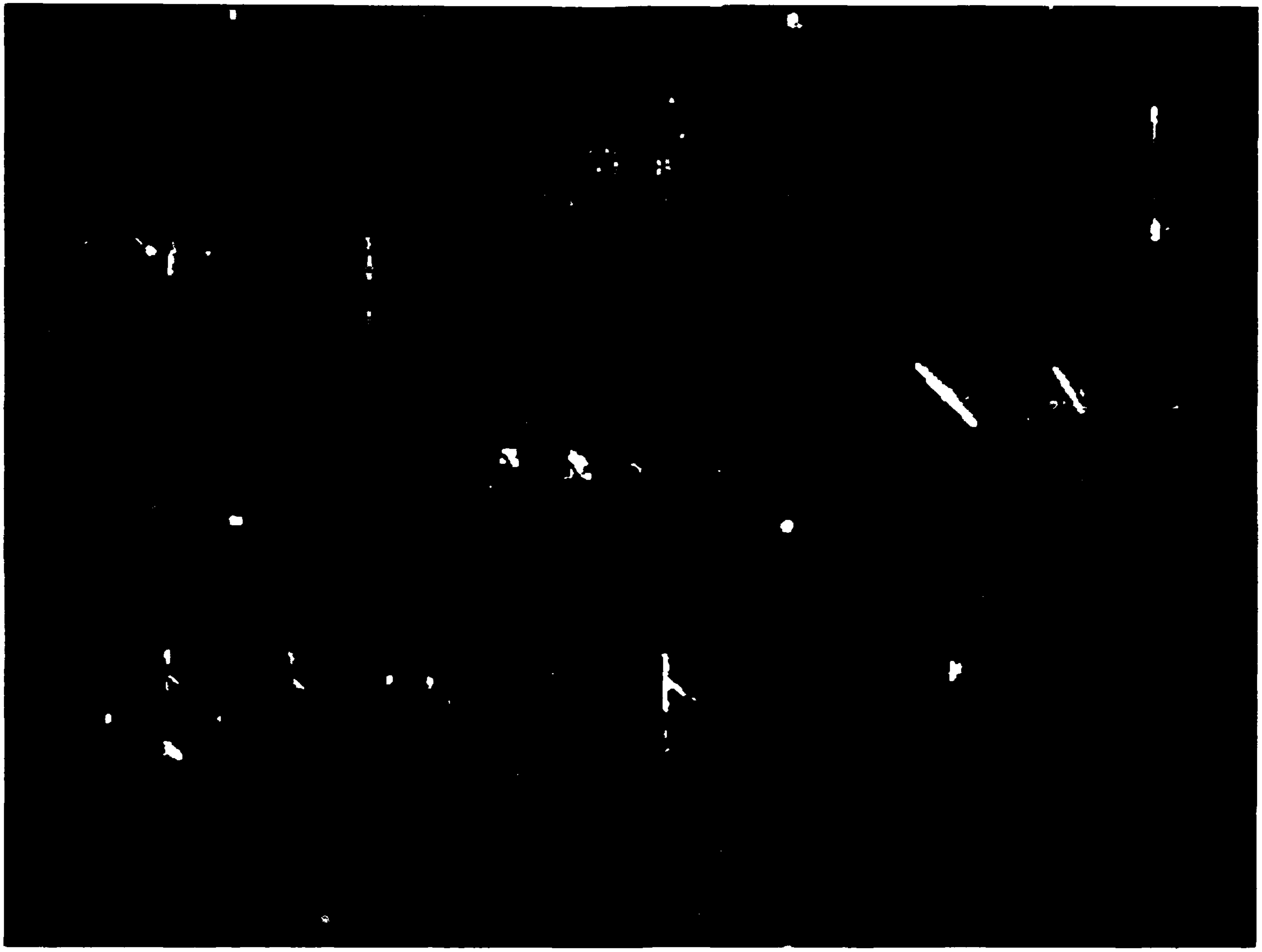

Fig. 3. All locations in Fig. 1 have a grey level/edge level combination which occurs less than 100 times in the entire image. These represent unique points which may indicate target locations.

Fig. 4. The average of Fig. 3 using a circular window of diameter 14.

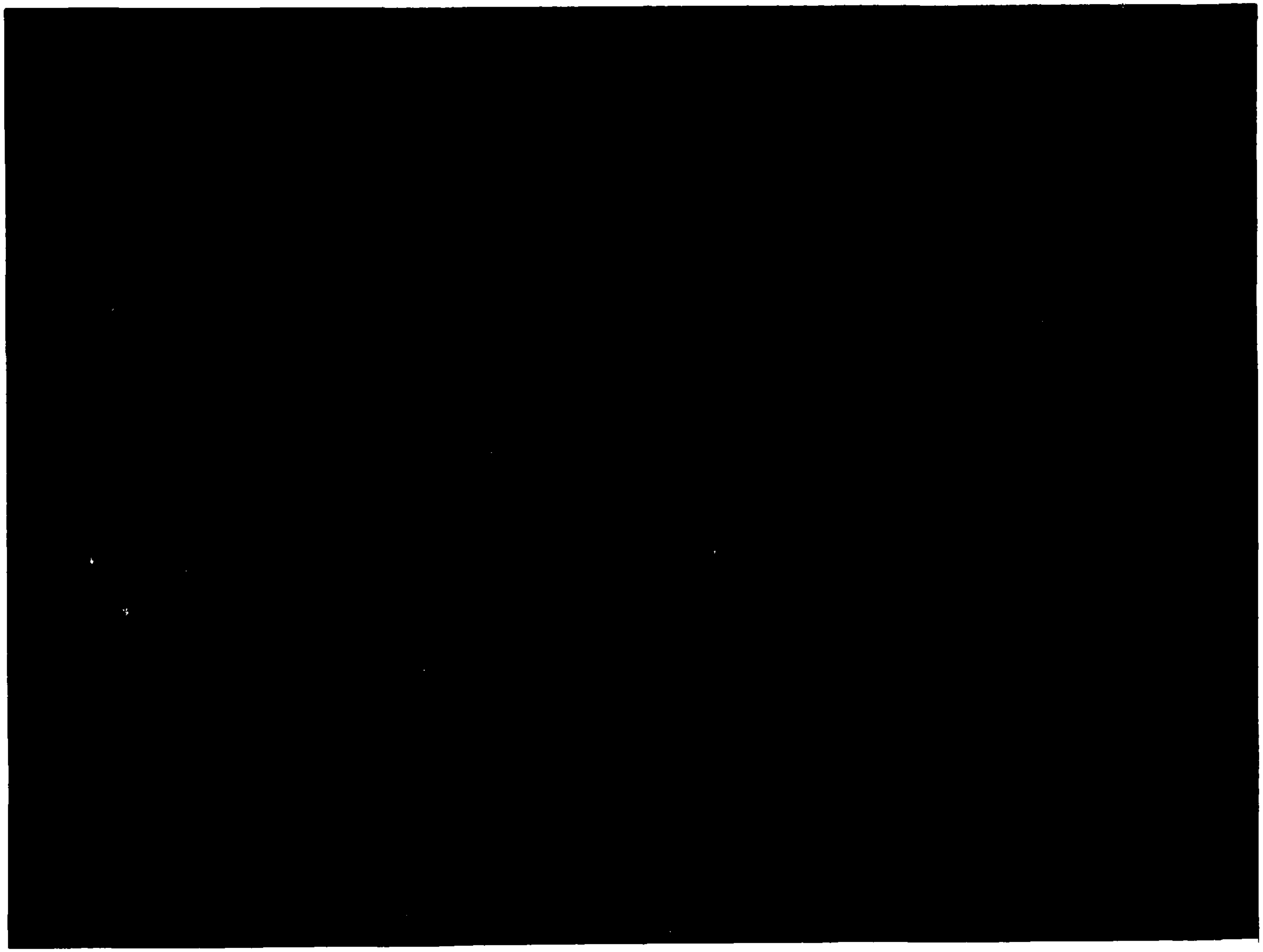

Fig. 5. The local maxima in Fig. 4. These represent the potential target locations in Fig. 1.

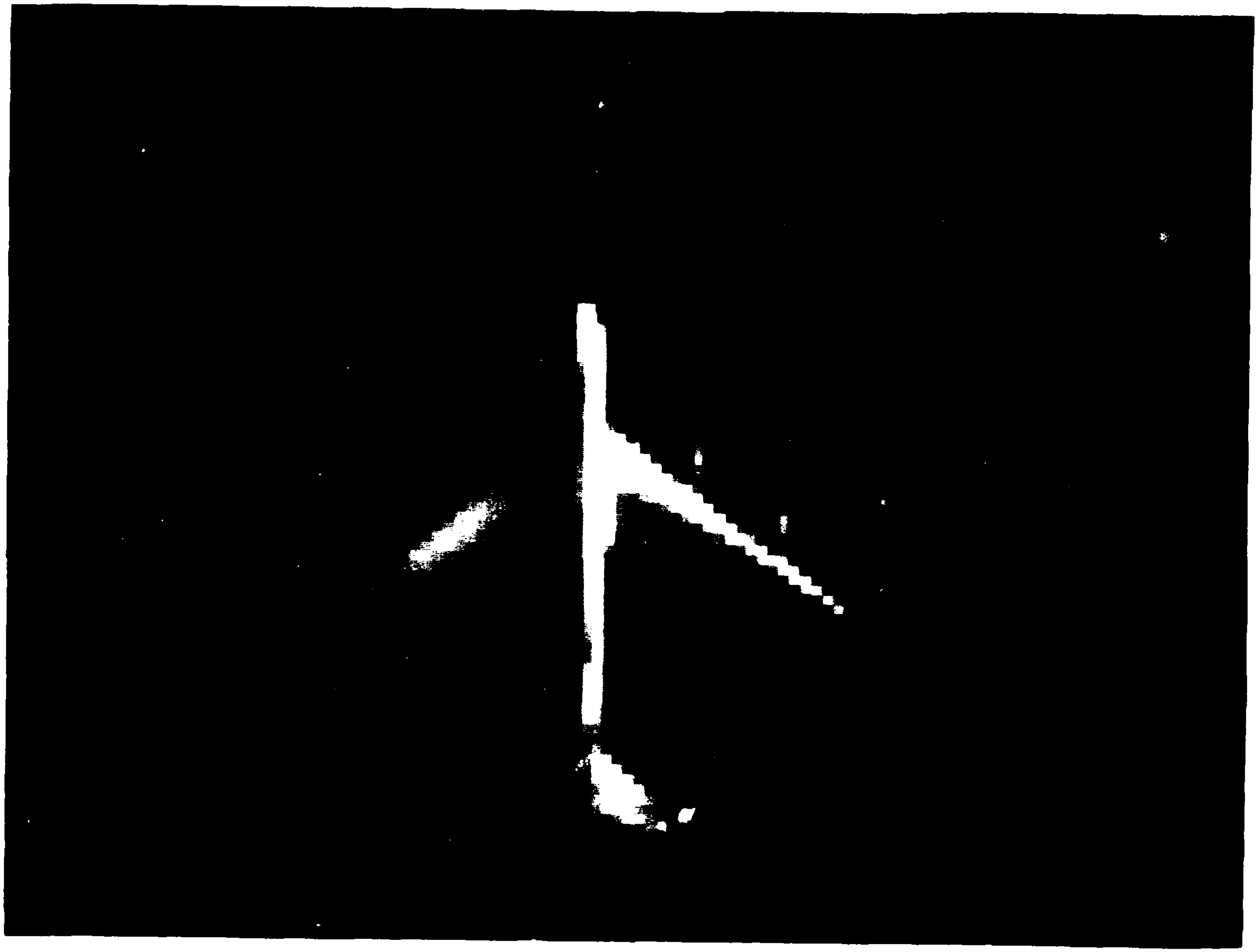

Fig. 6(a). A 100x100 region trimmed from the original in Fig. 1 which has its center point located at one of the potential target locations in Fig. 5.

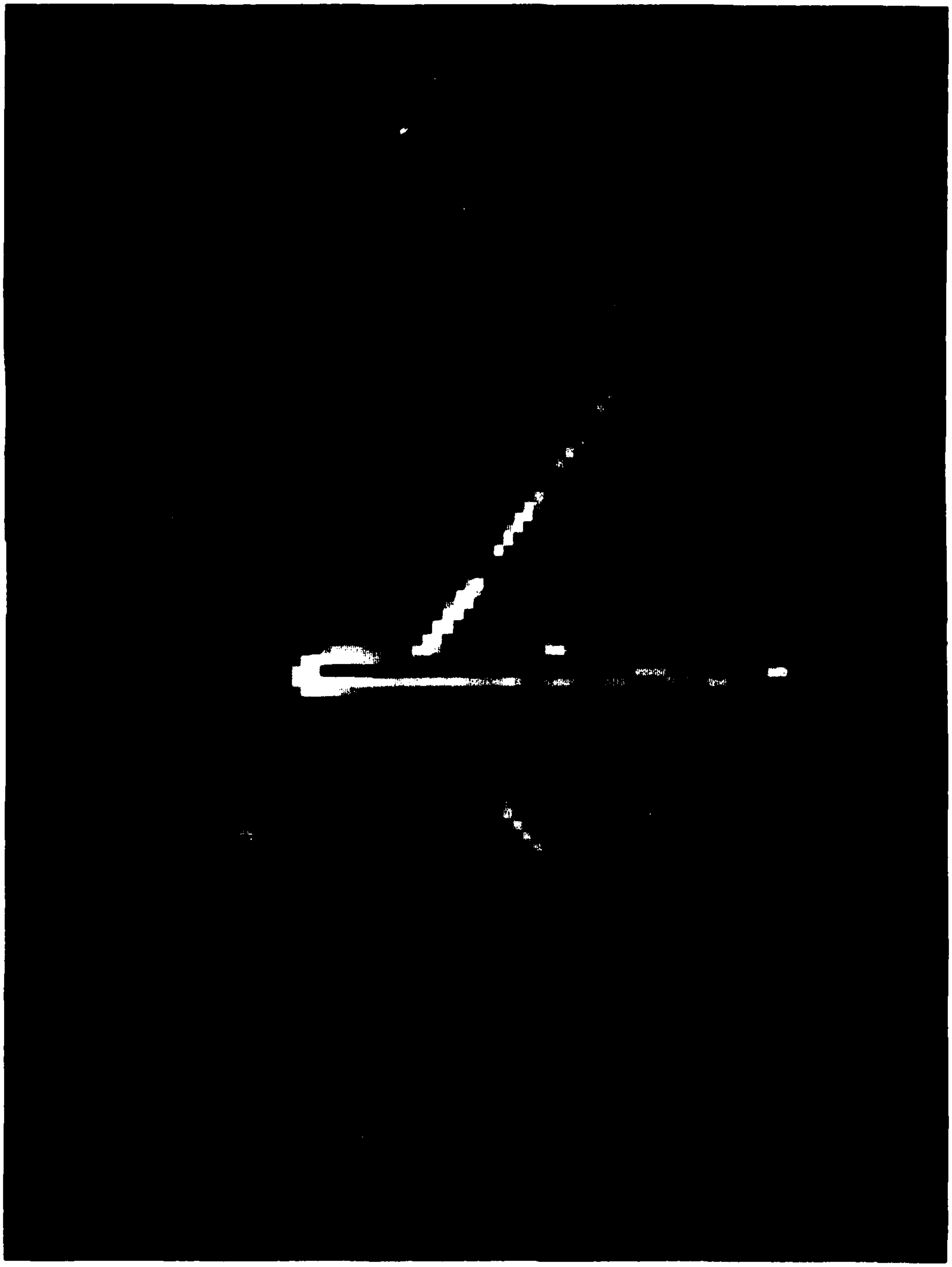

Fig. 6(b). The 100x100 Sobel edge image corresponding to Fig. 6(a).

and of the background under the constraint of spatial continuity. This might be considered a form of region growing. The image is divided into annuli defined by concentric circles, with origin at the center of the image, as shown in Fig. 7. The radius of each circle is such that there is an equal number of points in each annulus. Each annulus contains 480 points. Sixteen concentric circles at 480 points per annulus covers most of the 100x100 pixel image. A two-dimensional histogram of the number of occurences of each combination of grey level and edge in each annulus is generated using 32 levels of grey and 8 levels of edge.

In order to determine the histograms of the object and background, each two-dimensional vector count is observed as a function of radius. The initial estimates of the object and background histograms are determined by assuming that every vector which occurs in the innermost annulus and does not occur more than five times in the outermost annulus is an object vector. Any vector which occurs more than five times in the outermost annulus is a background vector. The object (background) histogram is incremented by the count of all the pixels in the current annulus having that object (background) vector. An initial estimate of the extent of the object is calculated as the boundary of the annulus for which ninety percent of the object vectors do not occur. Next all feature vectors that do not occur inside the maximum object radius are classified as background.

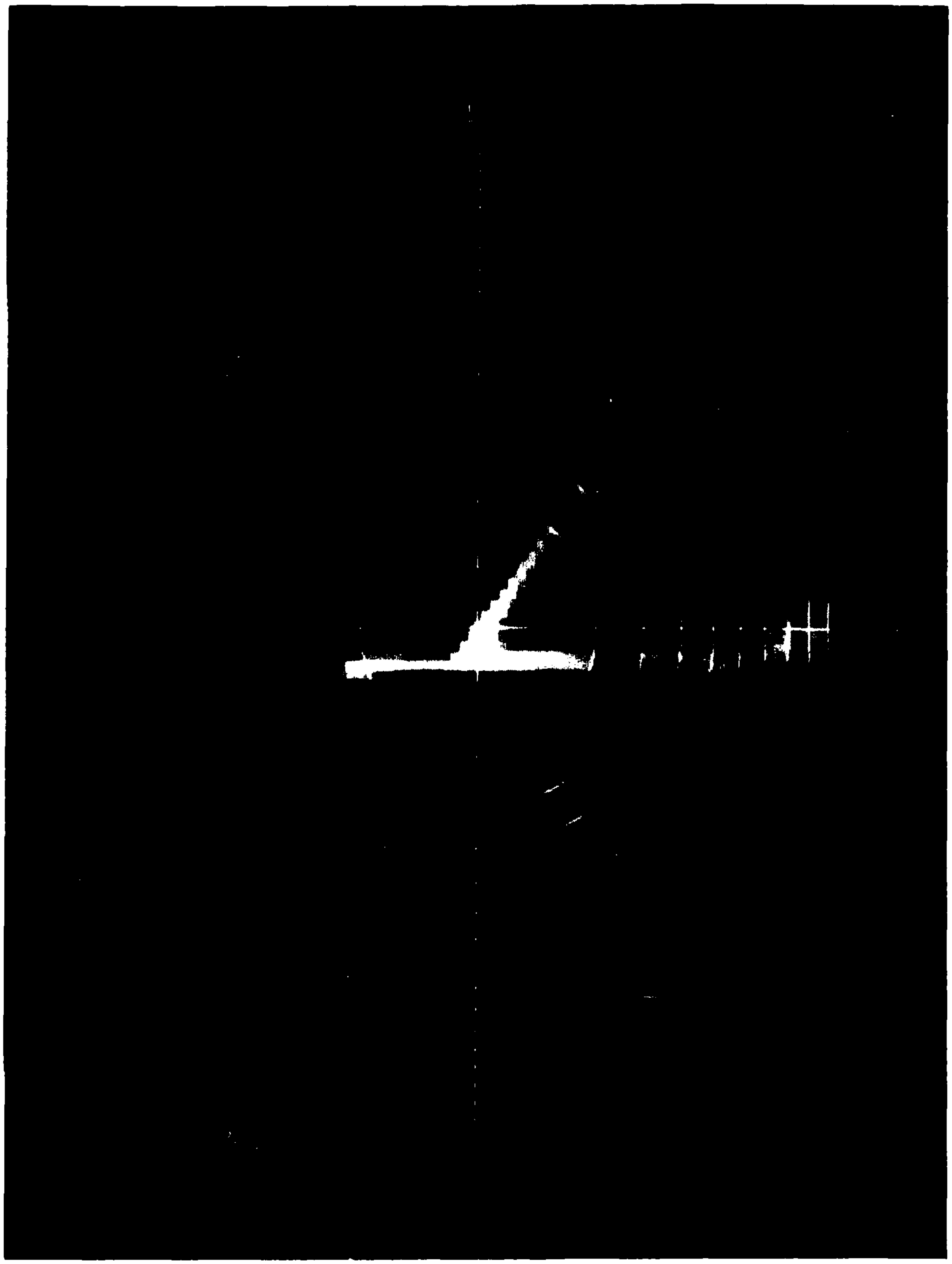

Fig. 7. The 16 annuli used in the segmentation (region growing) procedure to extract the potential target from the background. Each annulus contains 480 pixels.

At this point a major class of vectors normally remain unassigned: those vectors which do not occur in either the center or outermost region but begin occuring before the maximum object radius. This remaining class of vectors is assigned to either the background or the object histogram using the "majority nearest neighbor scheme" described next. Proceed from the innermost annulus to the annulus corresponding to the maximum object radius. Whenever an unclassified feature vector is encountered, calculate the number of object pixels and background pixels that map into same feature space neighborhood. The neighborhood is defined to be the vectors adjacent to the vector in consideration in the two-dimensional feature space. The feature space consists of data collected from the entire object. Assign the unclassified vector to be object or background based on the larger of the two counts. Update the object or background histogram to include all pixels having this feature vector.

Once all vectors are assigned, the image is again scanned and all points giving vectors occuring in the background or outside the object radius are set to zero. Thus the object is segmented from the background.

The results of this process operating on Fig. 6 is shown in Fig. 8. Note the broken wing due to the shadow in the original image. We have found that two stages of expansion (dilation) as shown in Fig. 9 are required to join such broken pieces. Two stages of contraction are then used to restore the object to its original size. The result is shown in Fig. 10.

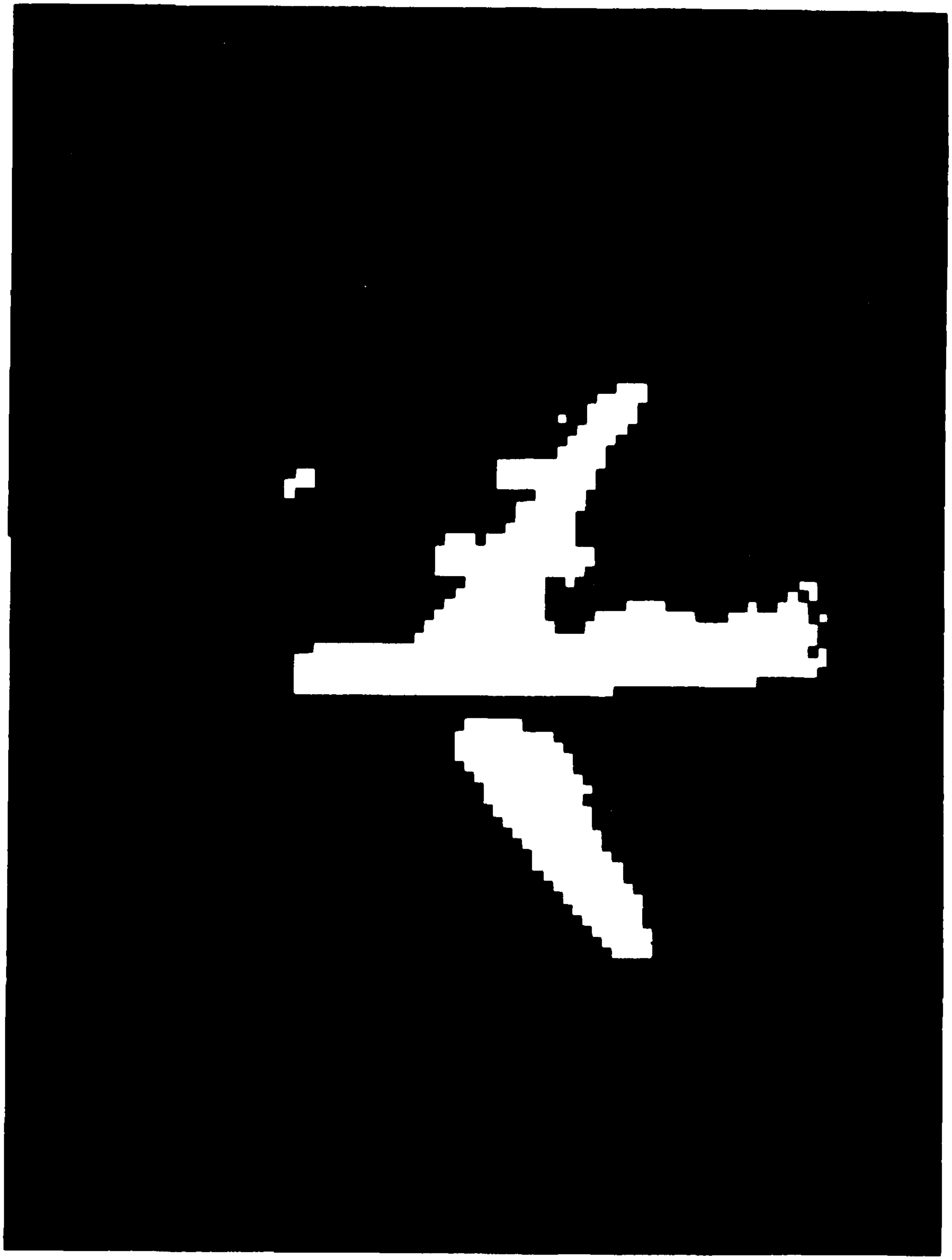

Fig. 8. The resulting segmented objects from Fig. 6. These points represent those which are different from the background in grey level and edge content.

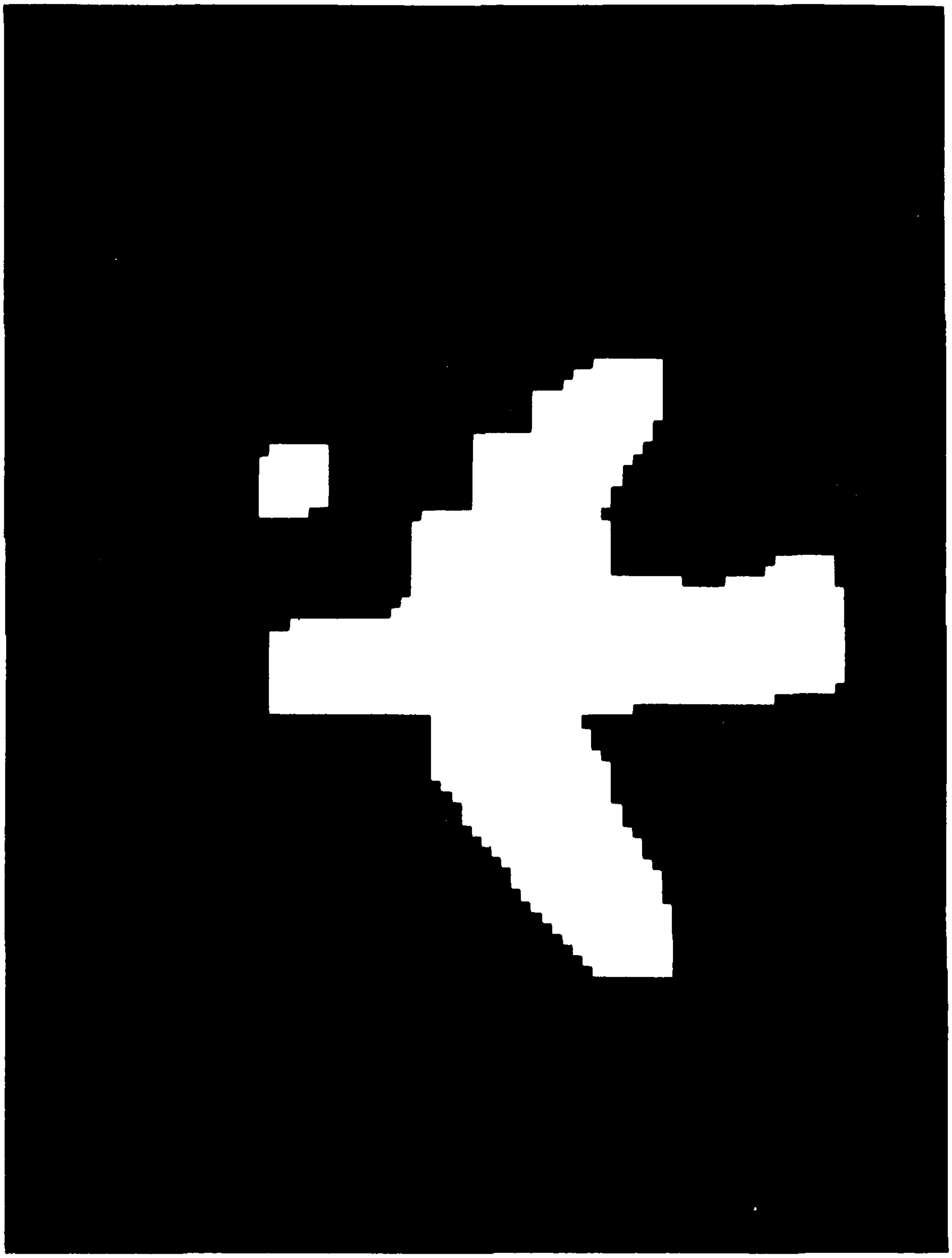

Fig. 9. The result of 2 successive applications of expansion (dilation) on Fig. 8.

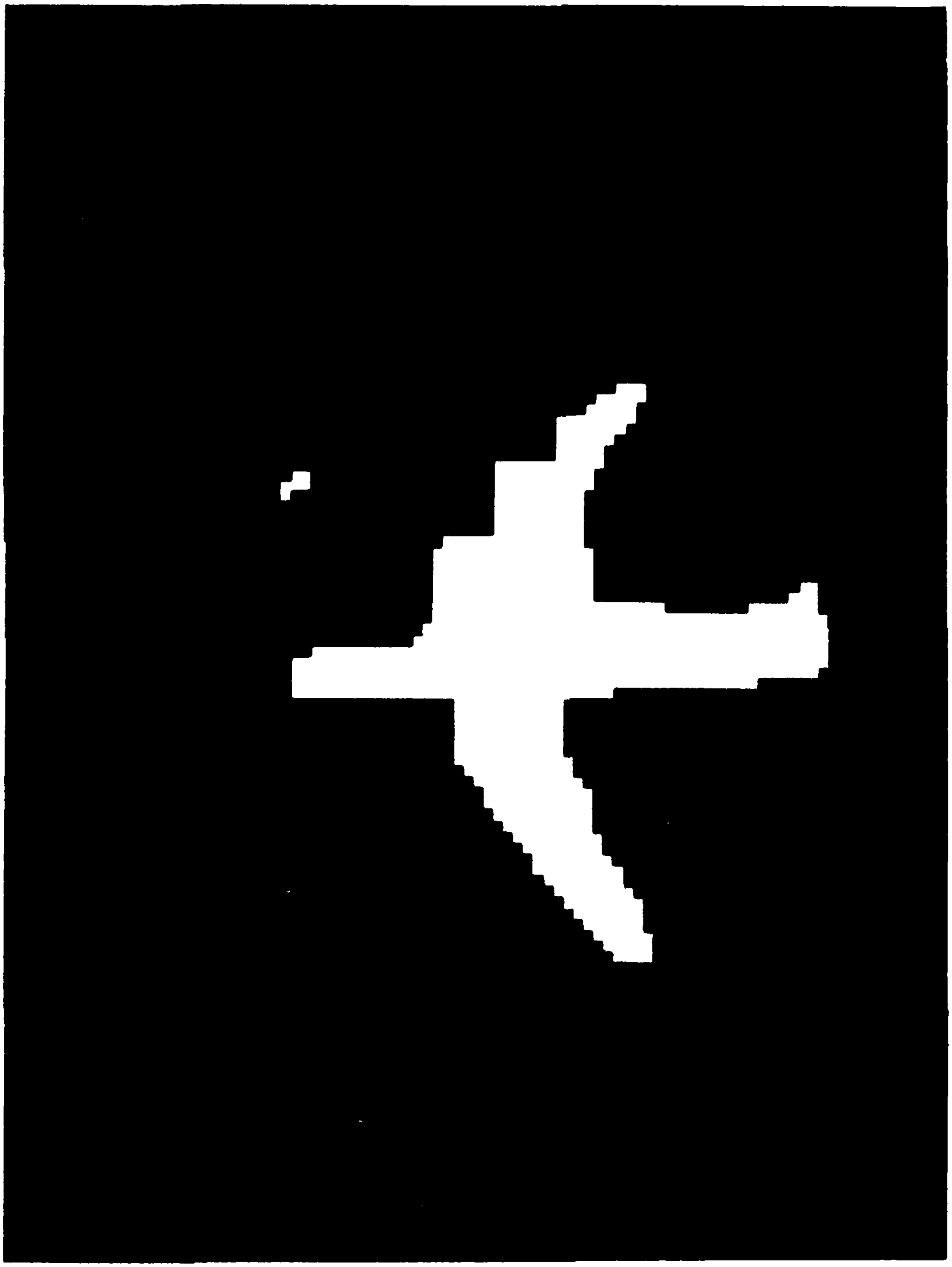

Fig. 10. The result of 2 succesive applications of contraction applied to Fig. 9.

The contour is traced around the segmented object and is shown in Fig. 11. When the same process as described in this section is applied to all the potential target points shown in Fig. 5, the contours shown in Fig. 12 result. These are the contours which are then input to the Fourier descriptor recognition system for classification.

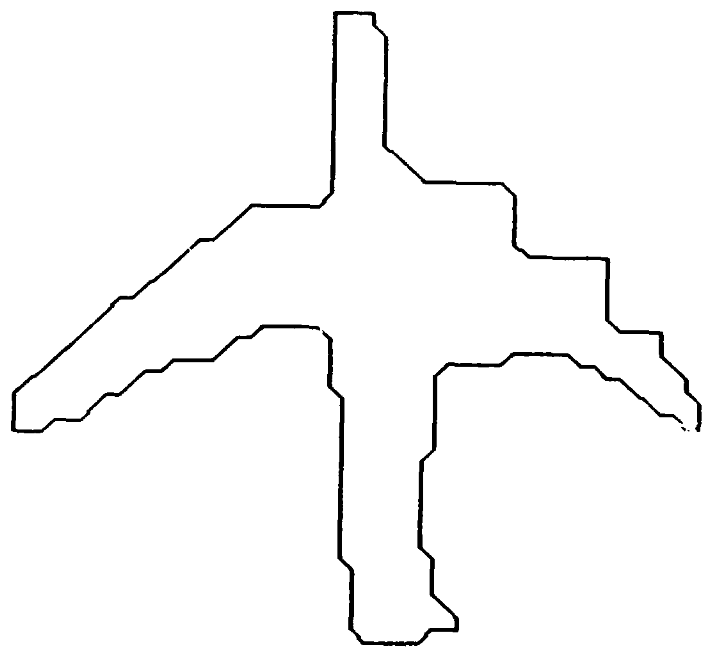

Fig. 11. The contour extracted from the segmented object as shown in Fig. 10.

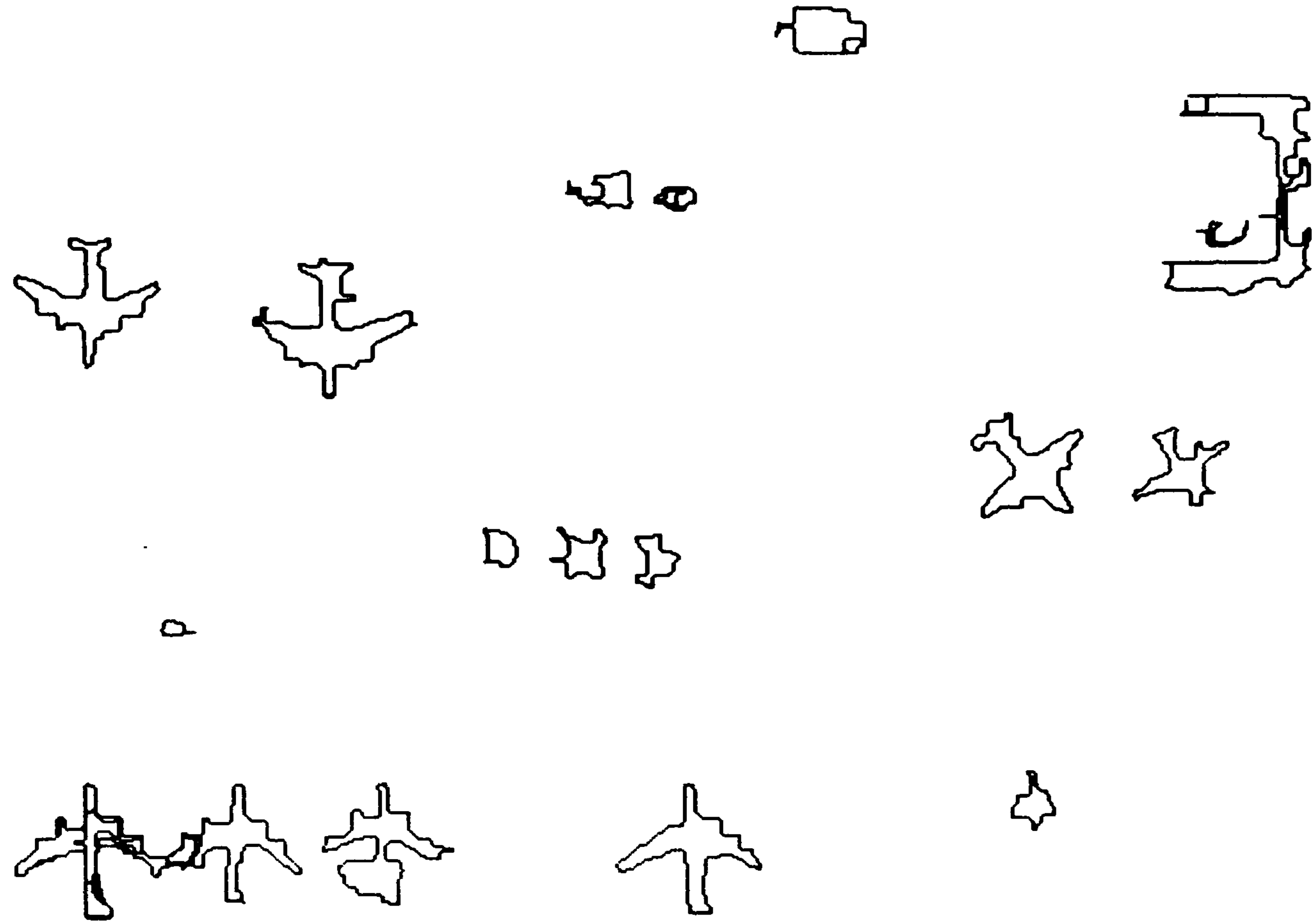

Fig. 12. All contours extracted from the original using the potential target locations shown in Fig. 5. These represent the contours to be classified by the Fourier descriptor method.

III. Contour Recognition

Each contour to be classified is first filtered (3% of total contour length) to remove noise. It is then resampled to a power of 2 to allow a Fast Fourier Transform. The Fourier descriptor is calculated and is normalized with respect to scale, translation, rotation, and starting point of trace. Ref. [2] contains details of the normalized Fourier descriptor algorithm.

The normalized Fourier descriptor is then compared to stored library entries of various targets (in this case, airplanes). For the tests described here, the library airplane contours were extracted from the photographs by tracing them on a digitizing table. The actual traced contours are shown in Fig. 13. Also shown are the shapes obtained by inverting the Fourier coefficients which were actually used in the libraries. If the unknown contour Fourier descriptor matches a library entry to within 12% mean-square error, the contour is classified as an airplane. The percent mean-square error is found by dividing the sum of the mean-square differences between each Fourier coefficient in the unknown and the library entry by the sum of the squares of the unknown coefficients and multiplying by 100%. The contours classified as airplanes are shown in Fig. 14. Eleven of the twelve airplanes were classified correctly giving a classification accuracy of 91%. One false alarm was also classified as an airplane.

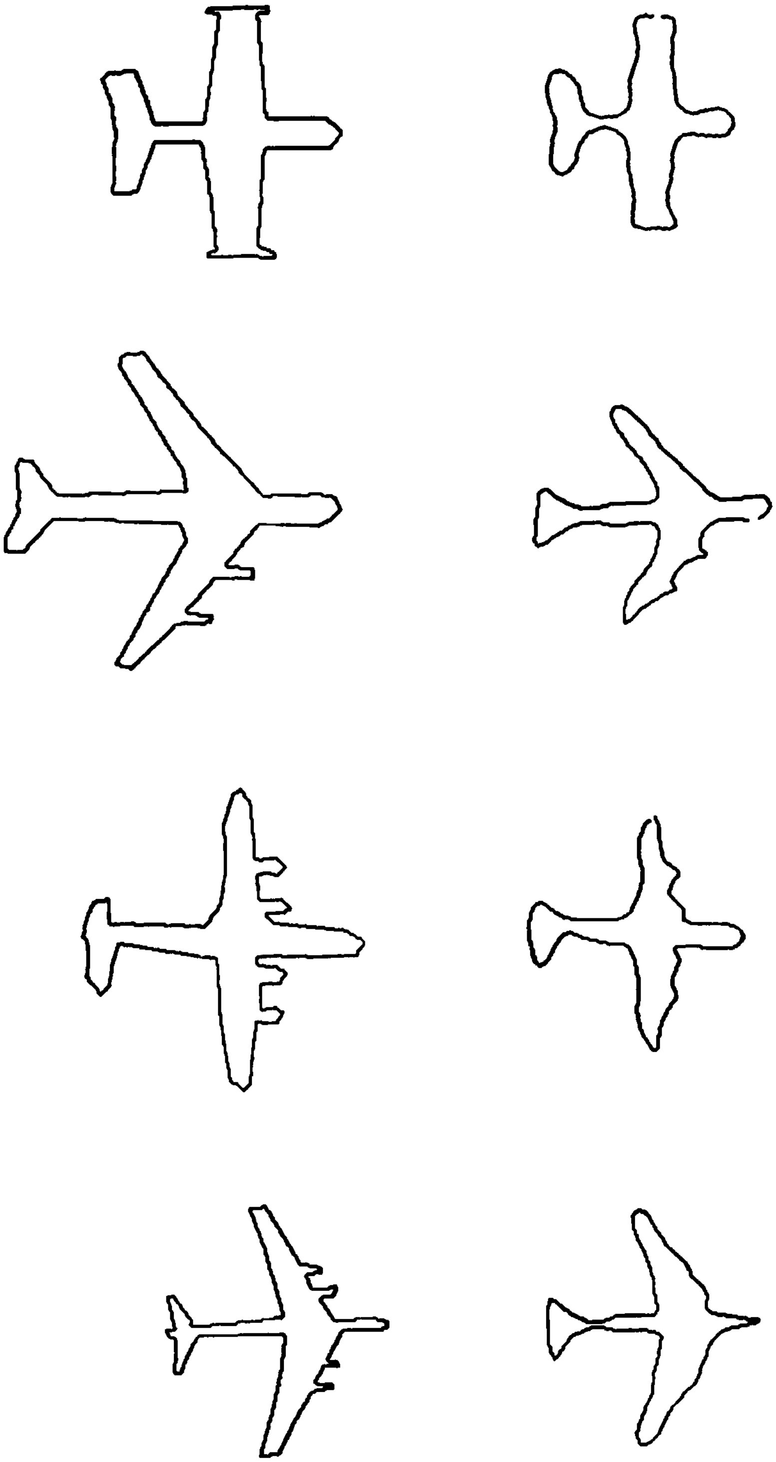

Fig. 13. The first column shows the four library airplanes obtained by using a digitizing table. The second column shows the shape obtained by inverting the first 16 Fourier harmonics of the contours shown in the first column.

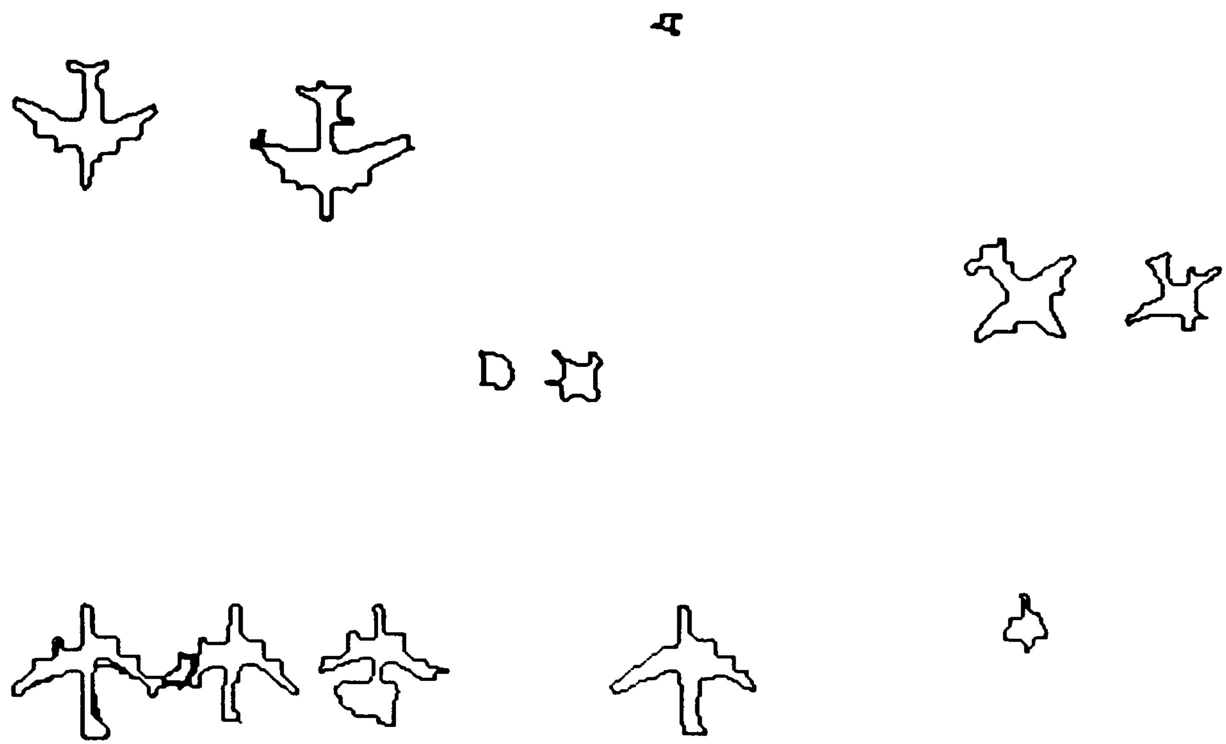

Fig. 14. All contours classified as airplanes by the Fourier descriptor shape recognition system.

IV. Timing Information

Although no effort has been made to optimize execution time of the algorithms implemented, some indication of the processing time required will be given. The times given are for a 512x512 picture using a VAX 11/780 computer:

Operation		Time
Derive edge feature picture (Sobel)	Fig. 2	118 sec
Locate potential targets (postarg)	Fig. 3	26 sec
(average)	Fig. 4	290 sec
(mountain)	Fig. 5	138 sec
Extract potential targets	Figs. 6-12	1202 sec
Classify all contours	Fig. 13	22 sec
Total Time		1796 sec

Thus of the 30 minutes required to process the picture, only 22 seconds were actually used in the classification of the contours and all the remaining time was used to extract the contours from the background.

V. Another Example

As a second example of this method, the photograph shown in Fig. 15 was used as an input to the same recognition system. Also shown in Fig. 15 is the edge picture. The unique grey level/edge level points are shown in Fig. 16(a) and the average of these points is shown in Fig. 16(b). The local maxima of the image in Fig. 16(b) represent potential target points which in this case are all accurate. The contours extracted as potential targets are shown in Fig. 17(a) and the contours actually recognized as airplanes are shown in Fig. 17(b). All are classified correctly.

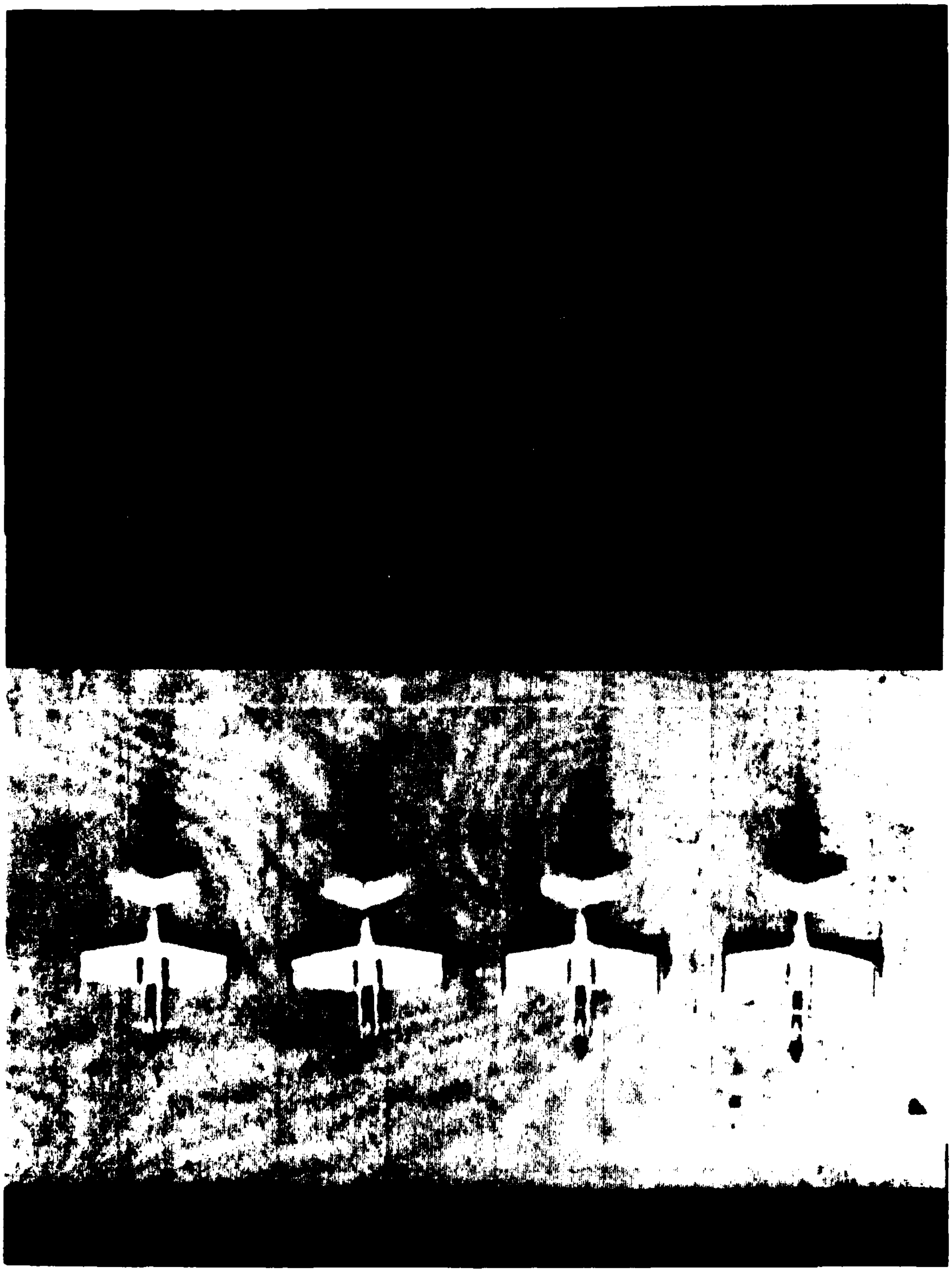

Fig. 15. (a) Left: Another original image to be processed: 256x512 pixels, 256 grey levels. (b) Right: The Sobel edge feature image derived from the original.

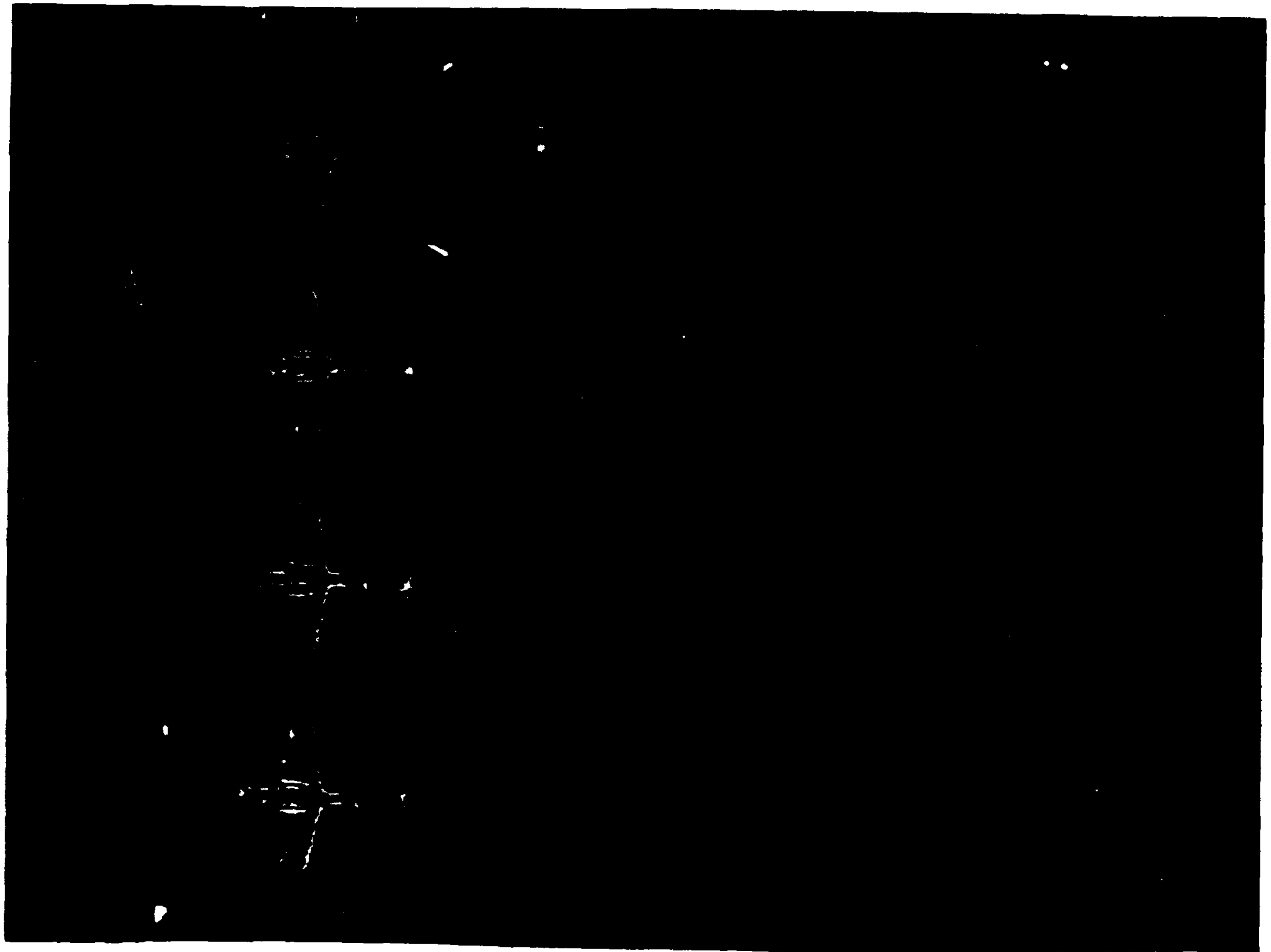

Fig. 16. (a) Left: All locations in Fig. 15 having a grey level/edge level combination which occurs less than 100 times in the entire image. (b) Right: The average over Fig. 16(a) using a circular window.

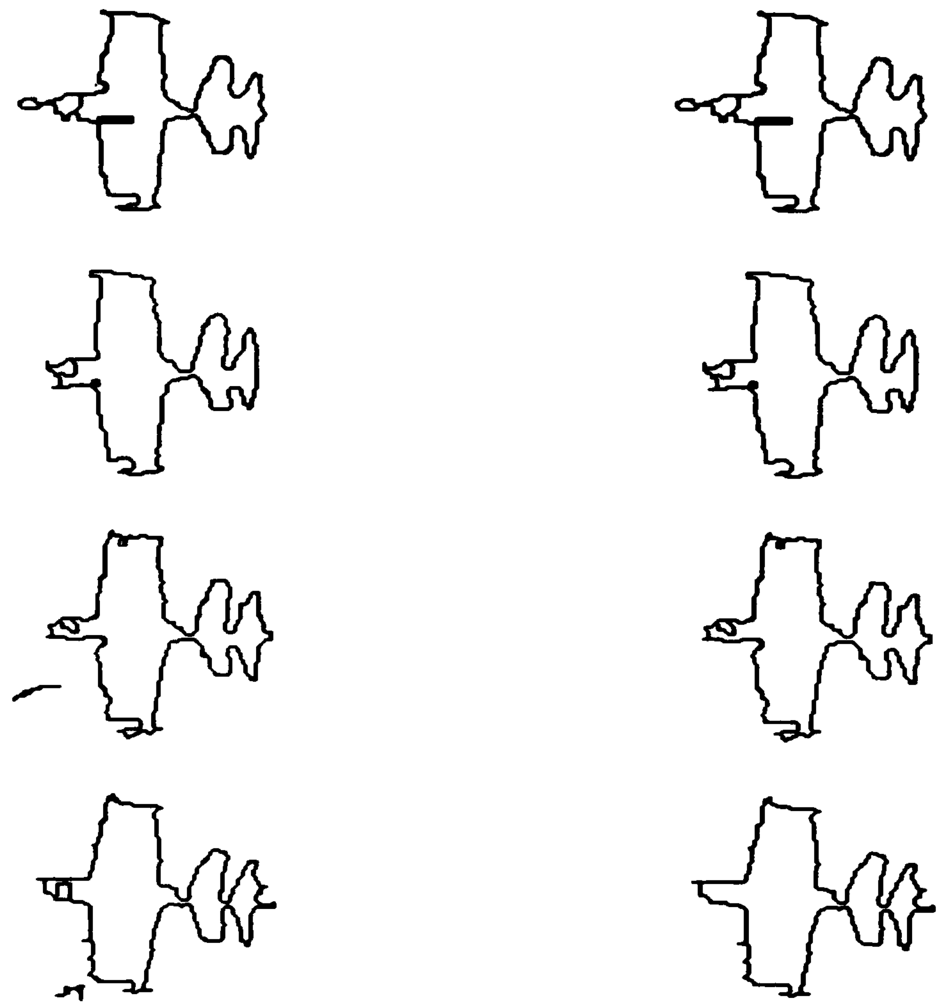

Fig. 17. (a) Left: All contours extracted from the original as potential targets using the segmentation method described in Sec. II.B. (b) Right: All contours recognized as airplanes by the Fourier descriptor recognition system.

VI. Discussion and Future Research

We have demonstrated the feasibility of extracting contours from aerial imagery and classifying these contours using a Fourier descriptor method. The most demanding task for images produced using sensors in the visible wavelengths is the extraction of the contours from the background (segmentation). We have demonstrated a method based on finding unique regions in grey level/edge level space which has this capability for the test images shown. The computer time required to do this is quite high (30 minutes for one 512x512 image). However the techniques described have parallel implementations which would allow very rapid speeds using a special purpose image processing system.

The Fourier descriptor method works very well when the extracted contours are accurate. However the presence of broken contours or partially wrong contours (such as caused by shadows) can give rapid deterioration in Fourier descriptor performance.

The following directions are suggested for future research:

(1) Improve the segmentation and contour extraction procedure by investigating the effects of parameter variations and the results of additional runs on various types of data.

(2) Investigate the implementation of the segmentation method on a parallel processing computer architecture and estimate the processing time required using the proposed machine.

(3) Improve the Fourier descriptor recognition method to include the combining of two partial contours to allow comparison to

one complete library contour. This would allow the segmentation method to output a broken object and have accurate recognition still occur.

(4) Compare the use of normalized moment descriptors with Fourier descriptors for accuracy on this type of data, and if useful, define a combined feature set which includes the best properties of both methods.

VII. References

[1] R. O. Duda and P. E. Hart, Pattern Classification and Scene Analysis, John Wiley, New York, 1973.

[2] T. P. Wallace and P. A. Wintz, "An Efficient Three-Dimensional Aircraft Recognition Algorithm using Normalized Fourier Descriptors," Computer Graphics and Image Processing, Vol. 13, pp. 99-126, 1980.

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